6 other years when the rainfall was less than that which has fallen so far this season. The record of these dry seasons is most instructive as it gives us the only indication of what may be expected in the way of rain for the next few months. The examination of average conditions is rarely satisfactory for the reason that the normal seldom if ever occurs. It is the exception that generally happens; and with this fact in view the following table has been compiled from the long rainfall record at this station. Only those seasons which resemble the present one have been considered.

Rainfall at San Diego, Cal.—Number of seasons in 62 years where less than half the normal was received up to Jan. 31.

Years.	Months.				Total, Oct. 1–Jan. 31.	Months.				Total, Oct. 1–May 31.
	Oct.	Nov.	Dec.	Jan.		Feb.	Mar.	Apr.	May.	
1863–64	0.0	0.73	0.04	0.04	0.81	2.50	0.20	0.01	1.25	4.77
1872–73	.0	.0	1.43	.44	1.87	4.21	.11	.10	.03	6.32
1876–77	.08	.04	.15	1.05	1.32	.18	1.44	.26	.43	3.63
1882–83	.41	.39	.13	1.09	2.02	.95	.41	.31	1.14	4.83
1886–87	.05	.95	.10	.04	1.14	4.51	.02	2.14	.47	8.28
1899–1900	.35	.86	.65	.69	2.55	.03	.53	1.26	1.45	5.82
1901–2	.28	.41	.02	1.70	2.41	1.57	1.86	.21	.06	6.11
1903–4	.07	.0	.35	.04	.46	1.50	2.17	.15	.12	4.40
1911–12	.28	.0	1.39	.66	2.33	.....	.....	.....	.....	.....
Means	.17	.38	.47	.64	1.66	1.93	.84	.56	.62	5.52

The season of least rainfall, that of 1876–77, showed less precipitation than any of the previous 27 years, and nothing has approached it in the 35 years that have elapsed. The history of that season shows that the last rain occurred on March 9, 1876, and until January 13 of the following year a total of only 0.65 of an inch was recorded. There appears to have been no damage to the orchards or inconvenience to other local interests, as the water storage was ample for all needs at that time. After this 10 months' drought nearly 3½ inches of rain fell.

It will be observed that February 1 marks the middle of the rainy season in San Diego. During a normal year 5 inches of rain falls after this date. In a dry year, like the present, the records show that nearly 4 inches of rain is liable to fall between this date and the end of May.

Normal rainfall by months.—September, 0.06 inch; October, 0.46 inch; November, 0.83 inch; December, 1.82 inches; January, 2 inches; February, 1.96 inches; March, 1.70 inches; April, 0.74 inch; May, 0.41 inch; June, 0.03 inch; July, none; August, none; year, 10.01 inches.

During the dry seasons referred to above the February rainfall averages 1.93 inches, generally falling in a few sharp showers accompanied by brisk to high southwesterly winds. In the cases where the March rainfall is considerable, like the years 1877 and 1904, the showers are more widely scattered. In fact, the records of the weather in San Diego during droughty periods indicate that downpours are common in February and occur during northerly storms, while March and April rains frequently result from southerly storms. During May the rains are largely of the "Sonora" type, being overflows from the Arizona disturbances. Rains from such storms often follow dense fogs. The character of the weather during seasons of light rainfall is very distinct and constitutes a class by itself, as shown by the pressure, temperature, winds, humidity, etc., which have been examined for each of these individual seasons. The records of the last few dry seasons have been studied in connection with the daily weather map and there is found to be a striking similarity in the distribution of the pressure areas. The past seasons resemble the present in that the widespread high areas are persistent and greatly outnumber the lows in their frequency, and the former possess far more energy. While it is impossible to make seasonal forecasts, a perusal of the tables which accompany this article would indicate that there is little likelihood of San Diego experiencing a severe drought, but that, on the contrary, there is every reason to believe that this region will receive not less than 3 or 4 inches more of rain during this season.

STUDIES IN FROST PROTECTION—EFFECT OF MIXING THE AIR.

By A. G. McADIE.

In a bulletin on Frost Fighting (Bulletin No. 29) issued by the Weather Bureau in 1900, three general principles were enumerated as effective in preventing frost. These were: 1, adding heat; 2, saving heat; 3, mixing or stirring the air.

By the direct addition of heat through such devices as coal baskets, fuel pots, and other orchard heaters of various types, much successful work has been done in raising the temperature in fruit orchards during critical times and thus preventing injury and subsequent loss.

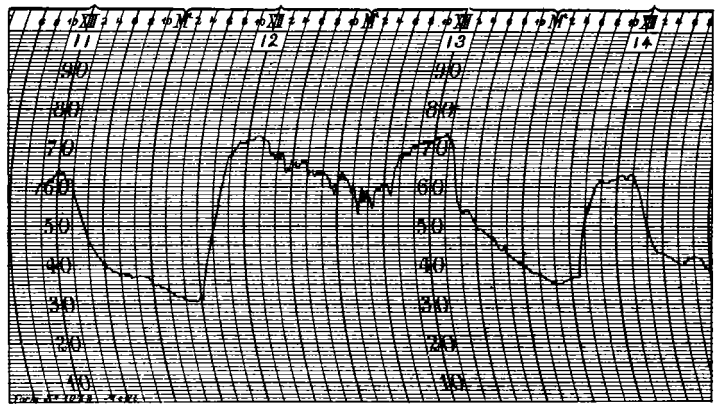

FIG. 1.—Temperature fluctuations at Kentfield, Cal., during period favorable for frost, Dec. 11–14, 1911.

Along the second line, that of saving he at, some work has been done in designing suitable covers. Much, however, remains to be done, and the problem of conserving the heat of the earth, plants, and the lower air is yet in an experimental stage. In many respects this is the cleanest and most efficient method of protecting.

Along the third line, that of mixing or stirring the air, suggestions have been made from time to time that windmills or electric fans could be arranged to insure circulation and prevent the formation of stagnant pools of air. In Farmers' Bulletin No. 104, issued November 27, 1911, the writer states on page 27 that so far as known no special devices suitable for commercial use in frost protection had been developed, making use of this principle of thorough ventilation:

> When nature mixes the air, i. e., on windy nights, frost does not occur. It is now known to meteorologists that layers of air of different temperatures may lie close to each other without mixing. On frosty nights there is often a difference of 6, 8, or 10° in temperature between the ground and the air 10 feet above, the warmer layers being uppermost. Where air is well mixed and there is good circulation, we seldom find frost.

An interesting illustration of the effect of stirring the air and the consequent prevention of low night and early morning temperatures is given by the accompanying thermograph record made at Kentfield, Cal., December 11 to 14, 1911. This is the base station for Mount Tamal-

pais, and its elevation is 65 feet above sea level. The station is 2,530 feet below the summit of the mountain, directly west.

The weather maps of the period show well-marked frost conditions. There were four nights on which frost might have been anticipated, and, as a matter of fact, killing frosts were general in the Sacramento and San Joaquin Valleys and in nearly all the bay valleys during the nights mentioned.

Referring to the Kentfield record, it will be seen that the night of December 11 and early morning of December 12 were marked by the characteristic rapid fall in temperature, and heavy frost occurred in the morning. The rapid rise from 31° at 6 a. m. to 68° by 10 a. m. of the 12th indicates the extreme dryness and purity of the air and also the absence of any marked convectional current. At noon of the 12th a temperature of 72° had been reached, while the temperature at the Weather Bureau station, 2,300 feet higher, was but 57°. Shortly after noon of December 12 the temperature at Kentfield began to fall; but the gradient is not as steep as it should have been under such conditions. The record shows great variability, and the whole character of the curve is unlike that of the preceding and following day. If an indicator card could have been constructed it would have shown that a large number of heat units had been saved during the night of the 12th and the early morning of the 13th through some agency. Conditions at the base station (Kentfield) are not sufficiently complete to indicate the cause of this variation in temperature; but taken in connection with the conditions prevailing in the free air nearly half a mile above the valley, it is plain that the conserving of the heat was due to a thorough mixing of the air. From the records which follow it will be seen that a moderate gale prevailed at the higher level during the period of unusual fluctuations at the lower level. There was a more or less thorough mixing of the air, extending down almost to sea level. The mean temperature for the period was approximately 65°, whereas under quiet conditions a mean temperature of about 52° would have resulted. The lowest temperature at the lower station was 53°, whereas under quiet conditions a minimum temperature of 29° might have occurred.

Mr. H. Legler, the official in charge at Mount Tamalpais, furnishes the following table of wind directions and velocities; also the hourly temperatures:

Dec. 12, 1911.	Wind.	Velocity.	Temperature.
		Miles.	*Degrees.*
Noon	North	25	57
1 p. m.	do	18	59
2 p. m.	do	19	59
3 p. m.	do	36	60
4 p. m.	do	41	60
5 p. m.	do	44	58
6 p. m.	do	45	58
7 p. m.	do	46	57
8 p. m.	do	48	57
9 p. m.	do	46	56
10 p. m.	do	45	56
11 p. m.	do	44	56
Midnight	do	42	55
1 a. m.	do	44	55
2 a. m.	do	46	54
3 a. m.	do	45	54
4 a. m.	do	46	53
5 a. m.	do	45	53
6 a. m.	do	45	53
7 a. m.	do	42	54
8 a. m.	do	43	54
9 a. m.	do	36	54
10 a. m.	do	29	55
11 a. m.	do	24	56

The atmospheric pressure, reduced to sea level, at 5 p. m., December 12, was 30.22 inches and at 5 a. m., December 13, 30.12 inches. The mean temperature for 24 hours from December 12, noon, to December 13, noon, was 56°. The atmospheric condition was one of extreme dryness; the weight of the water vapor, in grains per cubic foot, varied from 0.18 to 0.68.